Harmonic Phase Transitions in the DEQF: From Electron Charge to Quark Color

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Abstract

We propose that the fractional electric charges of quarks and the threefold structure of color charge emerge as sequential phase transitions of the Dark Energy Quantum Field (DEQF). In this framework, the electron/positron represents the fundamental oscillation of the DEQF, defining the unit of electric charge. Quark charges arise as the third harmonic of this oscillation, leading naturally to $\pm\frac{1}{3}$ and $\pm\frac{2}{3}$ quantization. Color charge is then interpreted as a resonance among the three orthogonal phase orientations of the quark harmonic, stabilized by the triadic invariant of the DEQF. This cascade of resonant transitions unifies electron charge, quark fractional charges, and color confinement within a single phase-transition ladder, offering a physical explanation for the longstanding "threeness" of the Standard Model.

Notation

P_0: DEQF static pressure; ρ: order parameter amplitude; θ: phase angle; $\phi = 3\theta$: harmonic phase; J_μ: conserved current.

1 Introduction

The Standard Model contains several numerical coincidences that have long puzzled theorists: fractional quark charges and the threefold replication of color. Anomaly cancellation arguments and GUT embeddings account for consistency but not physical origin. In the *Triadic Resonance Hypothesis*, we showed that the privileged role of three arises from cubic invariants of the DEQF. Here, we extend that work by proposing that charge quantization and color emerge from harmonic phase transitions.

2 Notation

Symbols. P_0 (DEQF static pressure); $\Psi = \rho e^{i\theta}$ (order parameter); ρ (amplitude); θ (phase); $\phi \equiv 3\theta$ (third-harmonic phase); J_μ (Noether current); λ (locking strength); α, β (potential coefficients); ϵ_{ijk} (Levi–Civita); d_{abc} (SU(3) symmetric tensor).

3 Order Parameter and Potential

We define the DEQF phase field as an order parameter

$$\Psi = \rho e^{i\theta}. \tag{1}$$

A minimal effective potential with triadic locking is

$$V(\theta) = \alpha \cos\theta + \beta \cos(3\theta), \quad |\beta| \gg |\alpha| \text{ in the quark sector.} \tag{2}$$

The dominance of the $\cos(3\theta)$ term produces three inequivalent minima separated by $2\pi/3$, naturally identifying three phase orientations with the three color charges. Minima are at $\theta_\star \in \{0, 2\pi/3, 4\pi/3\}$ with curvatures $V''(\theta_\star) = -\alpha\cos\theta_\star - 9\beta\cos(3\theta_\star) \approx 9|\beta|$, so domain walls prefer Z_3 sectors.

4 From Phase Winding to Charge Fraction

Derivation stub for thirds. In the $n = 3$ harmonic sector define $\phi \equiv 3\theta$. The conserved current $J_\mu = \kappa\, \partial_\mu \phi$ integrates over a 2π cycle in ϕ to one electron unit e. Hence a $2\pi/3$ advance in θ carries charge $e/3$. Allowed quark modes correspond to $\Delta\theta = \{\pm 1, \pm 2\} \times 2\pi/3$, yielding $\pm 1/3, \pm 2/3$.

Why not fifths. With $V(\theta) = \alpha\cos\theta + \beta\cos 3\theta$ and $|\beta| \gg |\alpha|$, only three deep minima exist, separated by $2\pi/3$. No gauge-invariant cubic invariant stabilizes five equally spaced minima without lower-order instabilities; putative $n = 5$ sectors fragment into Z_3 domains. Electric charge is treated as the Noether charge of a $U(1)$ symmetry acting on θ. In the $n = 3$ harmonic sector we define $\phi \equiv 3\theta$, with conserved current

$$J_\mu = \kappa \partial_\mu \phi. \tag{3}$$

A 2π cycle in ϕ corresponds to one electron unit e, so a $2\pi/3$ advance in θ carries charge $e/3$. Allowed quark modes correspond to $\Delta\theta = \{\pm 1, \pm 2\} \times 2\pi/3$, yielding charges $\pm 1/3, \pm 2/3$.

5 Group-Theory Handshake: SU(3)

The three phase orientations map naturally to the Z_3 center sectors of SU(3). The DEQF cubic invariant

$$\mathcal{L}_{\text{lock}} = -\lambda\, \epsilon_{ijk} d_{abc} J_i^a J_j^b J_k^c$$

produces SU(3)-invariant locking, ensuring that only triplet/antitriplet composites are unconfined.

Phase orientation θ	SU(3) color basis	Composite singlets
0	Red (R)	
$2\pi/3$	Green (G)	
$4\pi/3$	Blue (B)	
$R + \bar{R}$, $G + \bar{G}$, $B + \bar{B}$	–	Meson singlets ($3 \otimes \bar{3} \to 1$)
R + G + B	–	Baryon singlet ($3 \otimes 3 \otimes 3 \to 1$)

Table 1: Phase orientations mapped to SU(3) colors. Only Z_3-neutral composites form singlets, corresponding to mesons and baryons.

6 Hypercharge and the Gell-Mann–Nishijima Relation

The third-harmonic sector rescales the $U(1)$ generator such that quark hypercharges fall naturally on thirds. This reinterprets $Q = T_3 + Y/2$ with normalization fixed by the harmonic structure.

Worked example. Take the left-handed quark doublet (u_L, d_L) with $T_3 = \{+\frac{1}{2}, -\frac{1}{2}\}$ and assign $Y_q = \frac{1}{3}$ in the harmonic normalization. Then

$$Q(u_L) = +\tfrac{1}{2} + \tfrac{1}{2}\left(\tfrac{1}{3}\right) = \tfrac{2}{3}, \tag{4}$$

$$Q(d_L) = -\tfrac{1}{2} + \tfrac{1}{2}\left(\tfrac{1}{3}\right) = -\tfrac{1}{3}, \tag{5}$$

while the electron doublet with fundamental normalization has $Y_\ell = -1$ giving $Q(e_L) = -1$. The $n = 3$ harmonic effectively rescales the $U(1)$ generator so allowed representations land on thirds. The third-harmonic sector rescales the $U(1)$ generator such that quark hypercharges fall naturally on thirds. For example: up quark ($T_3 = +1/2$, $Y = 1/3$) yields $Q = 2/3$, and down quark ($T_3 = -1/2$, $Y = 1/3$) yields $Q = -1/3$.

7 Confinement as Phase Recombination

Confinement follows naturally as phase recombination. The three locked orientations at $0, 2\pi/3, 4\pi/3$ sum to zero net winding, forming a color singlet. In this picture, isolated Z_3 defects are energetically costly and confine via linear flux tubes, whereas Z_3-neutral composites (mesons and baryons) propagate freely. A simple free-energy sketch illustrates how single-phase flux tubes are unstable, while Z_3-balanced triads minimize the energy and remain unconfined.

8 Consequences and Predictions

- **No stable $1/5$ charges.** The potential

$$V(\theta) = \alpha \cos\theta + \beta \cos(3\theta), \qquad |\beta| \gg |\alpha|$$

stabilizes only three deep minima, separated by $2\pi/3$. This construction forbids fifth-harmonic sectors. Existing experimental bounds on millicharged particles ($< 10^{-5}e$) are consistent with this exclusion.

- **Coupling modulation (numerical estimate).** Assume a density scaling law

$$\frac{\delta\alpha}{\alpha} \simeq \epsilon \frac{\rho}{\rho_{\rm nuc}},$$

with $\rho_{\rm nuc} \approx 2.8 \times 10^{17}\,{\rm kg\,m^{-3}}$. Taking $\epsilon \sim 10^{-8}$ yields $\delta\alpha/\alpha \sim 10^{-8}$ in neutron-star cores and $\delta\alpha/\alpha \lesssim 10^{-22}$ in laboratory-density solids — comfortably below current equivalence-principle and atomic-clock constraints.

- **CMB tensor damping (toy model).** During a brief phase-locking epoch, tensor modes obey

$$h_k'' + 2Hh_k' + c_T^2 k^2 h_k + 2\Gamma(a) h_k' = 0,$$

with $\Gamma(a) = \Gamma_0 (a/a_\star)^p$. Modes with $k \gtrsim k_\star$ where $\Gamma \gtrsim H$ are exponentially suppressed,

$$h_k \propto \exp\left[-\int \Gamma\, d\eta\right].$$

This predicts damping of tensor power beyond a multipole cutoff $\ell_\star \approx k_\star \chi_*$.

- **Condensed-matter analogs (tri-BEC).** Three-component Bose–Einstein condensates with engineered cubic coupling $\lambda\,{\rm Re}(\psi_1\psi_2\psi_3)$ should spontaneously select three locked phases at $0, 2\pi/3, 4\pi/3$. Only balanced triads propagate without domain walls; no stable five-phase states exist under the same sign structure.

9 Related Work

Charge quantization is usually addressed via anomaly cancellation (e.g., $\sum_i Q_i^3 = 0$), grand unification (SU(5), SO(10)), and monopole arguments. Confinement is often linked to $\mathbb{Z}_3$ center symmetry in lattice QCD and flux-tube pictures. Standard accounts also tie fractional charges to hypercharge assignments within GUT embeddings. Our approach differs: harmonic phase transitions in the DEQF impose a triadic structure that explains *why three* appears in geometry, the charge lattice (thirds), and color, without embedding the gauge group in a larger simple group.

10 Figures

11 Conclusion

We have extended the Triadic Resonance Hypothesis by showing how charge and color emerge through harmonic phase transitions in the DEQF. The third harmonic yields fractional charges, SU(3) color locking, and confinement as natural consequences. This mechanism explains "why three" by harmonic necessity.

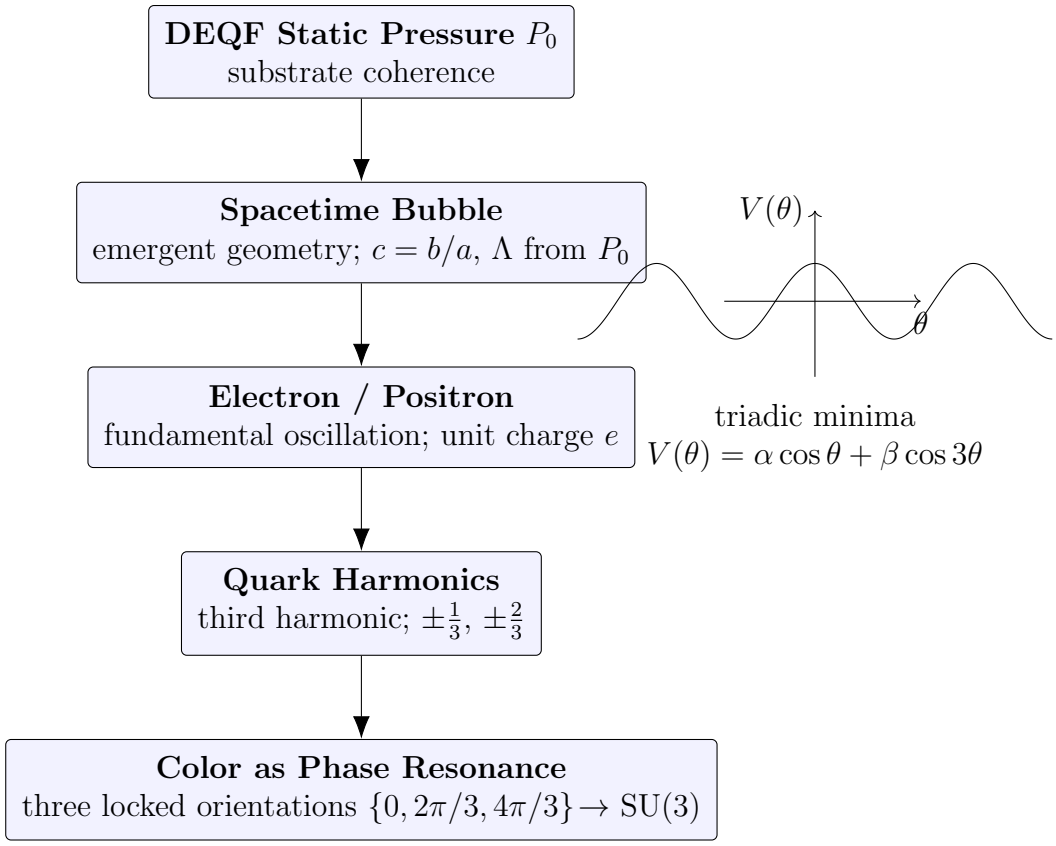

Figure 1: Phase-transition ladder of the Dark Energy Quantum Field (DEQF). Static pressure P_0 sets substrate coherence; spacetime geometry emerges with $c = b/a$ and Λ from P_0. The fundamental oscillation produces the electron/positron with unit charge e. The third harmonic yields quark charges $\pm\frac{1}{3}$, $\pm\frac{2}{3}$, and the three locked orientations $\{0, 2\pi/3, 4\pi/3\}$ map to SU(3) color. The free-energy sketch shows $V(\theta) = \alpha\cos\theta + \beta\cos 3\theta$ with triadic minima, enforcing the threeness underlying color and confinement.

A Toy Model: Three-Component BEC

Consider Gross–Pitaevskii equations for three fields ψ_i:

$$i\partial_t\psi_i = -\nabla^2\psi_i + g|\psi_i|^2\psi_i + g_{123}\psi_j\psi_k^*, \quad i \neq j \neq k. \tag{6}$$

For $g_{123} < 0$, the system locks phases at $0, 2\pi/3, 4\pi/3$, reproducing DEQF triadic behavior.

References

[1] J. S. Trimm, "A Complete Formulation of the Grand Unified Field Theory of Asymmetry: Spacetime and Gravity as Emergent Phases of the Dark Energy Quantum Field," (2025). Available at: https://archive.org/details/guft-asymmetry-complete

[2] J. S. Trimm, "Deriving the Speed of Light from the Expansion of Time and Space: A GUFT Perspective," (2025). Available at: https://archive.org/details/deriving-the-speed-of-light

[3] J. S. Trimm, "DEQF Static Pressure as the Source of c, Λ, the Arrow of Time, and the Matter–Antimatter Bias," (2025). Available at: https://archive.org/details/deqf-pressure-final

[4] J. S. Trimm, "GUFT Conservation Principles: Formalizing Trimm's Axiom and DEQF Pressure Coherence," (2025). Available at: https://archive.org/details/conservation-and-measurement-7

[5] J. S. Trimm, "Triadic Resonance in GUFT: Linking Space, Color, and Charge," (2025). Available at: https://archive.org/details/triadic-6